Critical role of Maritime Continent Water Cycle on the Indonesian Throughflow

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Material based on Lee, Fournier, Gordon, and Sprintall (2018)
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Motivation

- The MC is a low-latitude chokepoint of global ocean circulation, with the Indonesian throughflow (ITF) going through the MC, affecting ocean, climate, & BGC *(e.g., Godfrey 1996, Lee et al. 2002, Sprintall et al. 2014)*
- SSS in the MC affects ITF vertical structure and thus Indo-Pacific exchanges *(e.g., Gordon et al.2003, Nature)*
- Paucity of in-situ salinity data in the MC hinders the understanding of ocean-water cycle linkages

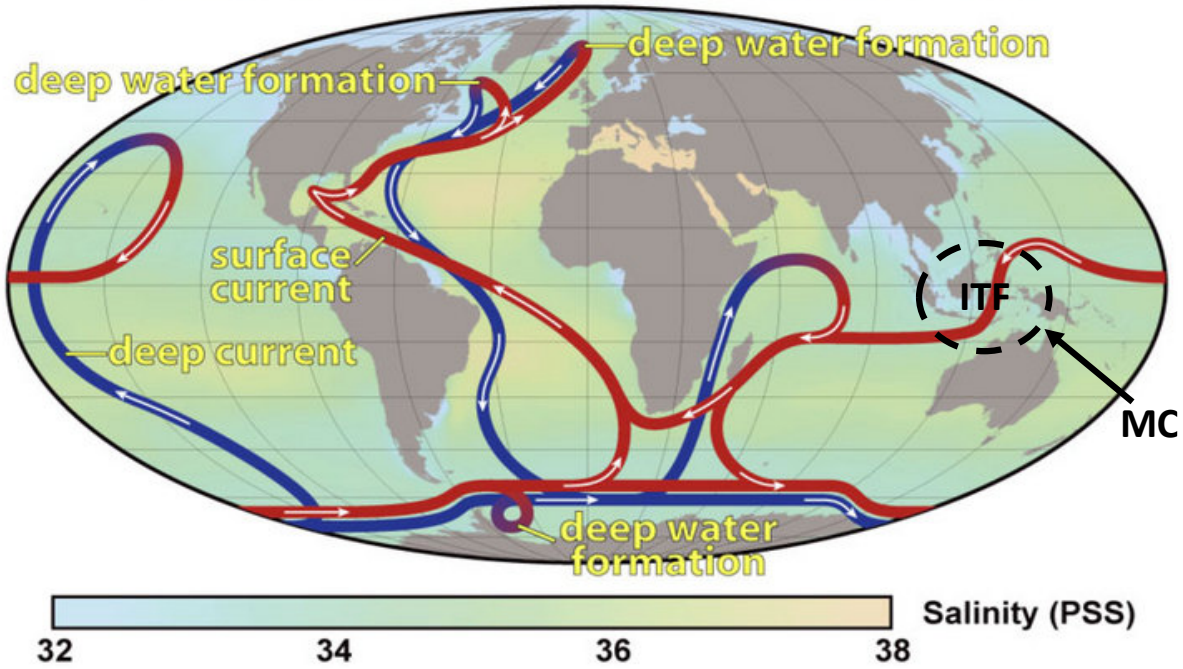
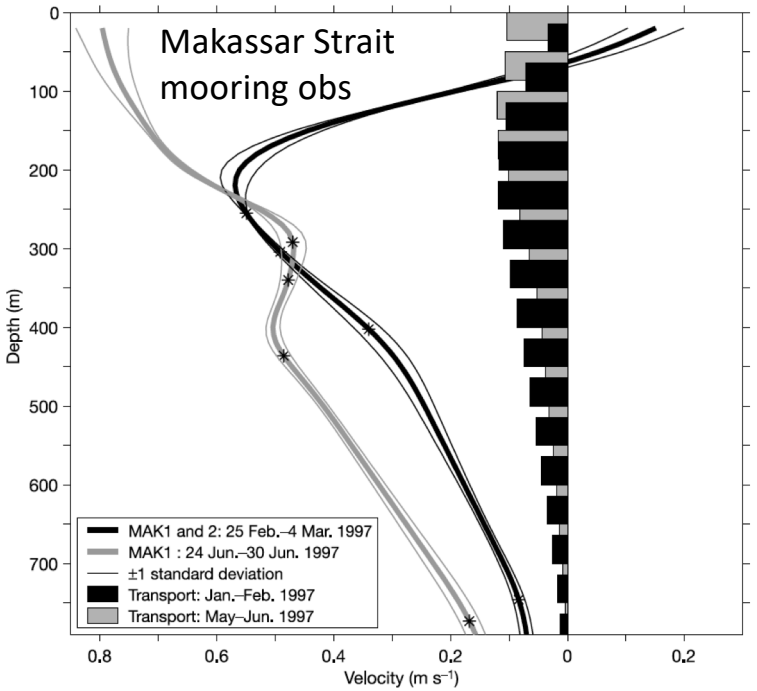


Image credit: Aquarius.oceansciences.org

Upper-layer ITF much weaker in boreal winter due to low SSS



An important knowledge gap: the source of the low SSS that influences the ITF

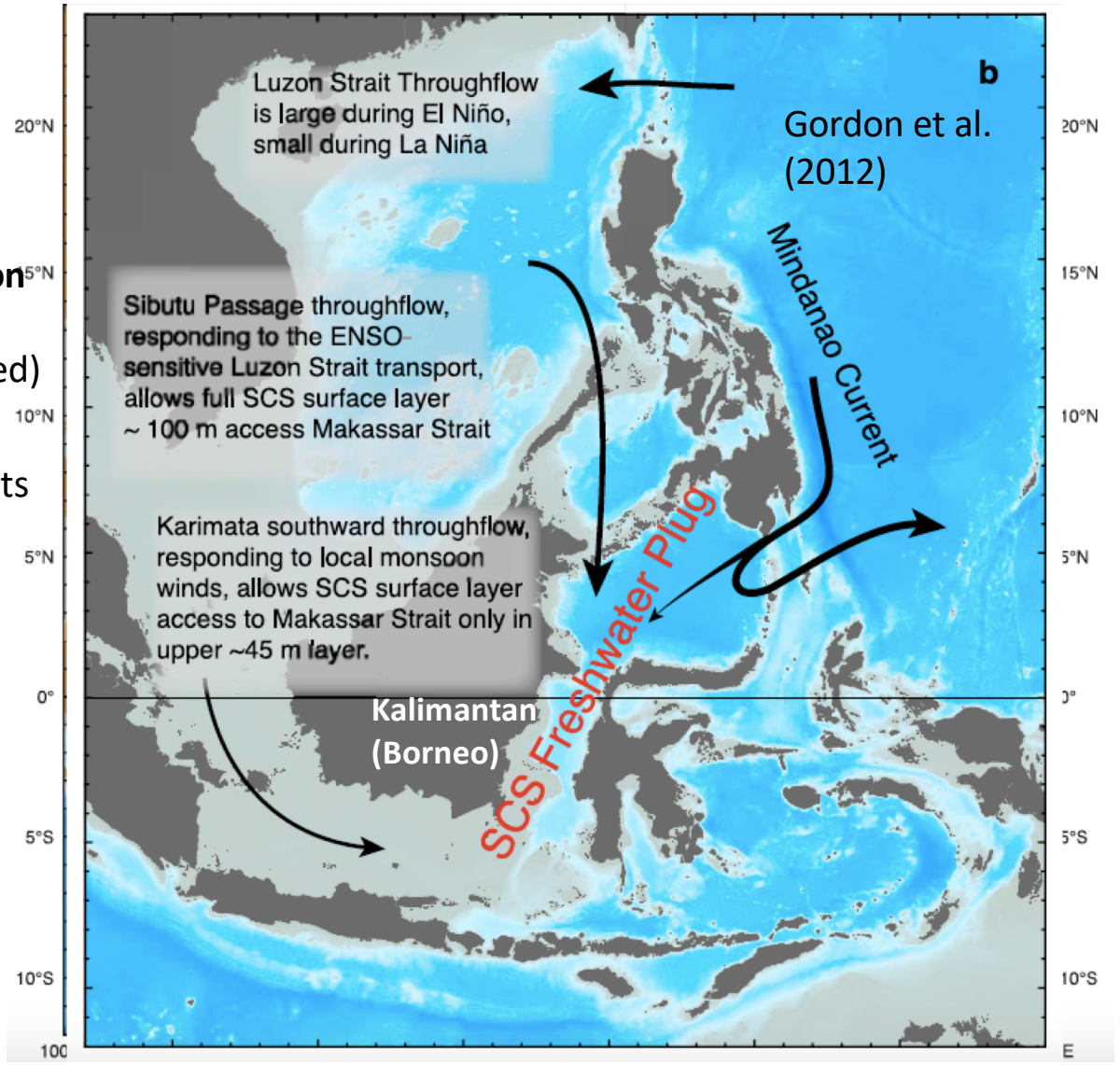
Schematics of southeast Asian Seas circulation

- Indonesian throughflow (ITF) (solid)
- South China Sea throughflow (SCSTF) (dashed)

Previous studies suggested SCSTF & SCS freshwater modify the ITF structure & transports *(e.g., Qu et al. 2005, Tozuka et al. 2007/2009, Fang et al. 2010, Gordon et al. 2012).*

However, the effects of MC regional water cycle (local precip & runoff) have not been investigated

Here we examined these effects on the freshwater plug & the ITF



Ocean-atmosphere-land satellite observations

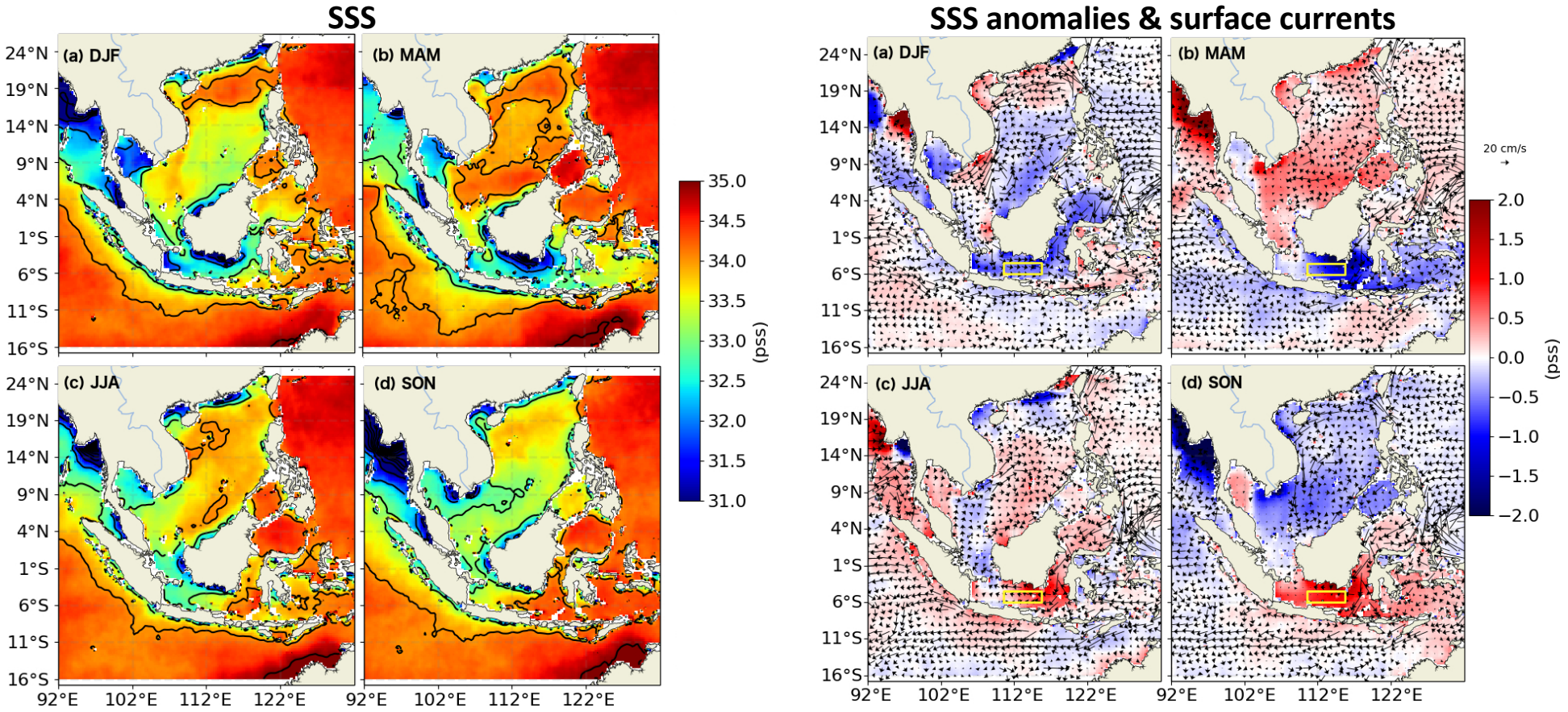
Parameter	Satellite	Resolution
SSS	SMAP V3 JPL	~50 km (0.25° grid)
SSS	SMOS CATDS (only to Dec. 2017)	~55 km (0.25° grid)
Precipitation	TRMM/GPM	10 km
Soil moisture	SMAP	~40 km (0.25° grid)
Ocean color (Colored Dissolved Organic Matter – CDOM)	MODIS	1 km
Sea Level Anomaly (SLA)	Merged altimetry (AVISO)	0.25° grid
SST	Reynolds OISSTv2	0.25° grid

Other products

Ocean surface currents	HYCOM operational data assimilation OSCAR satellite-derived currents	1/12° 1/4°
Evaporation	OAFLUX (only to Dec. 2017)	1°
In-situ SSS climatology	WOA2013	0.25°

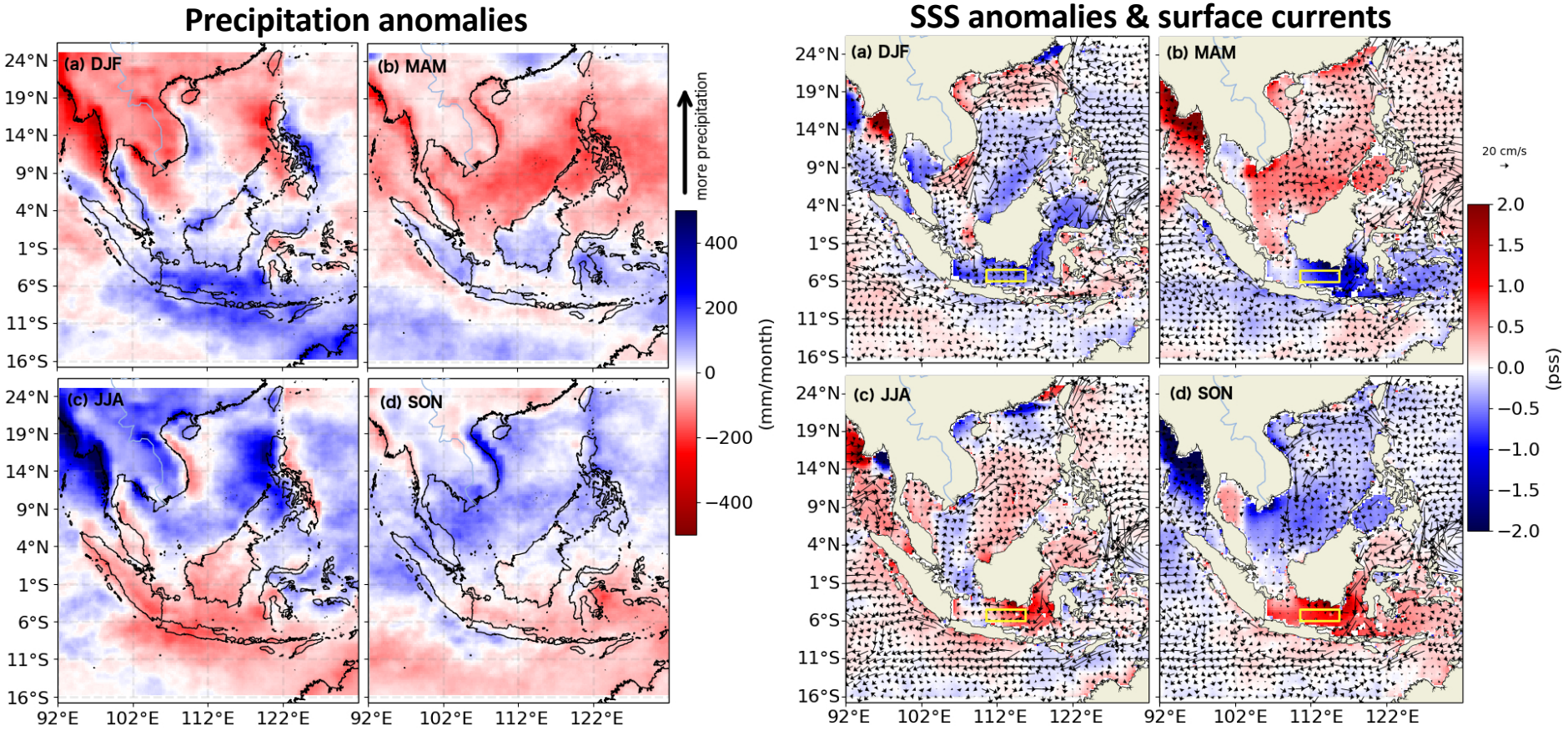
Analysis period: focused on April 2015-March 2018 (SMAP period)

Seasonal composites of SMAP SSS & SSS anomalies (relative to time mean)



- Seasonal freshwater plug exists not only in boreal winter, but boreal spring as well
- SCS waters not fresh enough to explain the seasonal freshwater plug
- Low SSS hugs the coasts of Kalimantan, implicating runoff effect

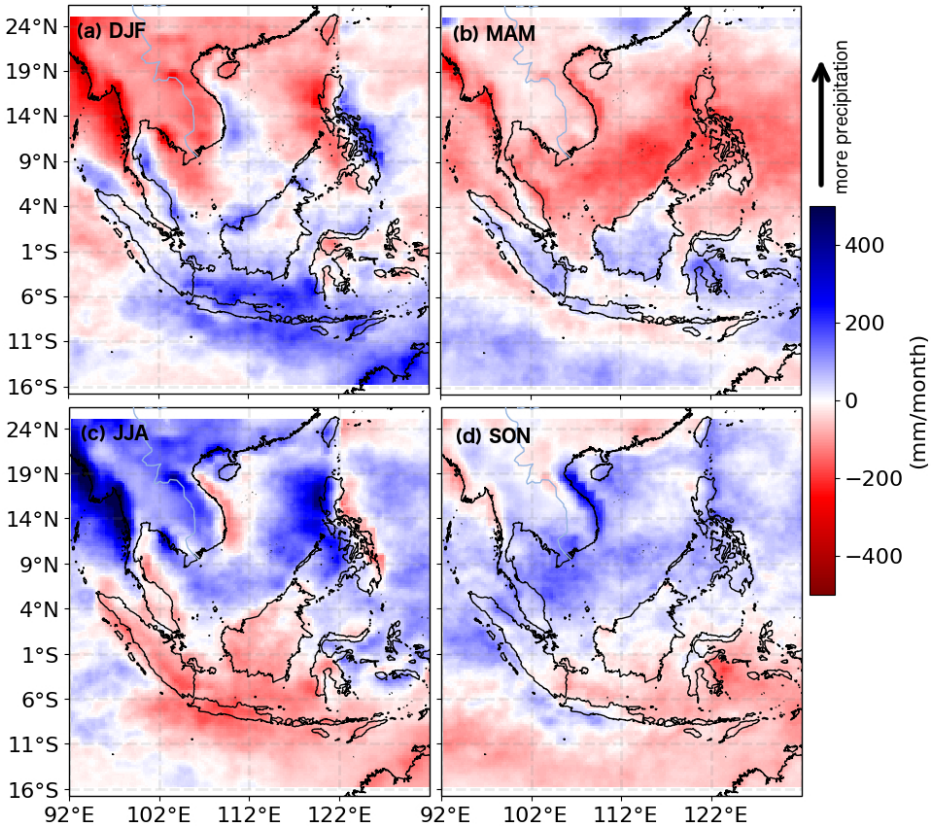
Seasonal anomalies of precip in Java Sea suggest significant impact on SSS anomalies



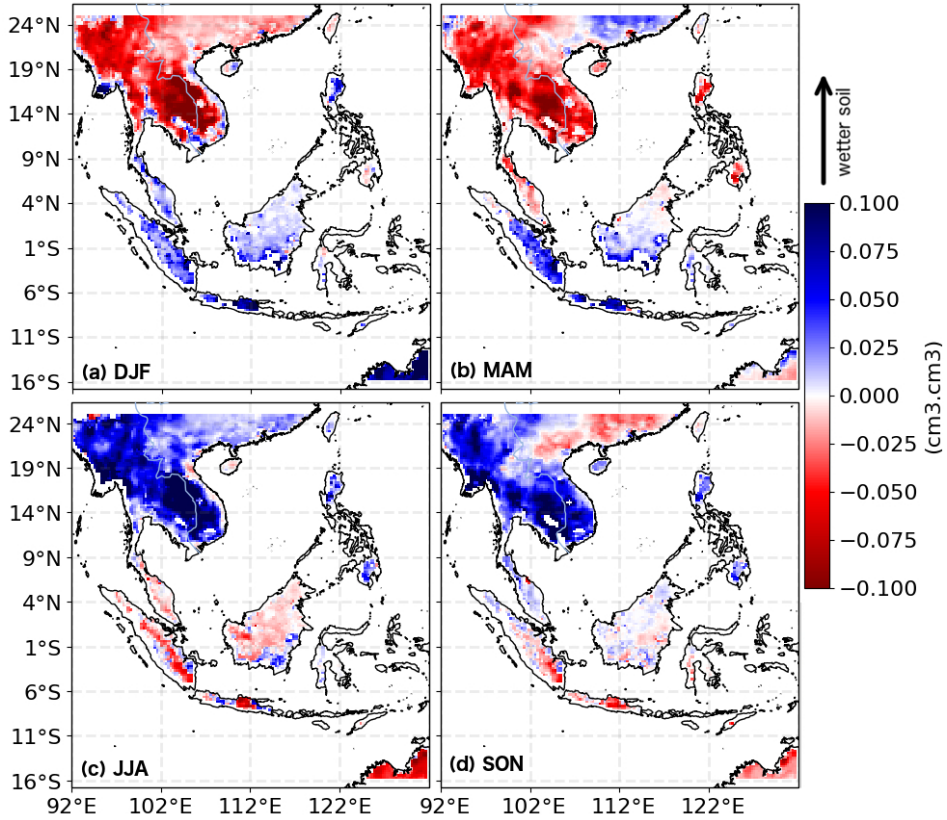
(see quantitative SSS budget analysis later for the yellow box)

Boreal winter-spring precip & soil moisture anomalies in Kalimantan implicate runoff

Precipitation anomalies

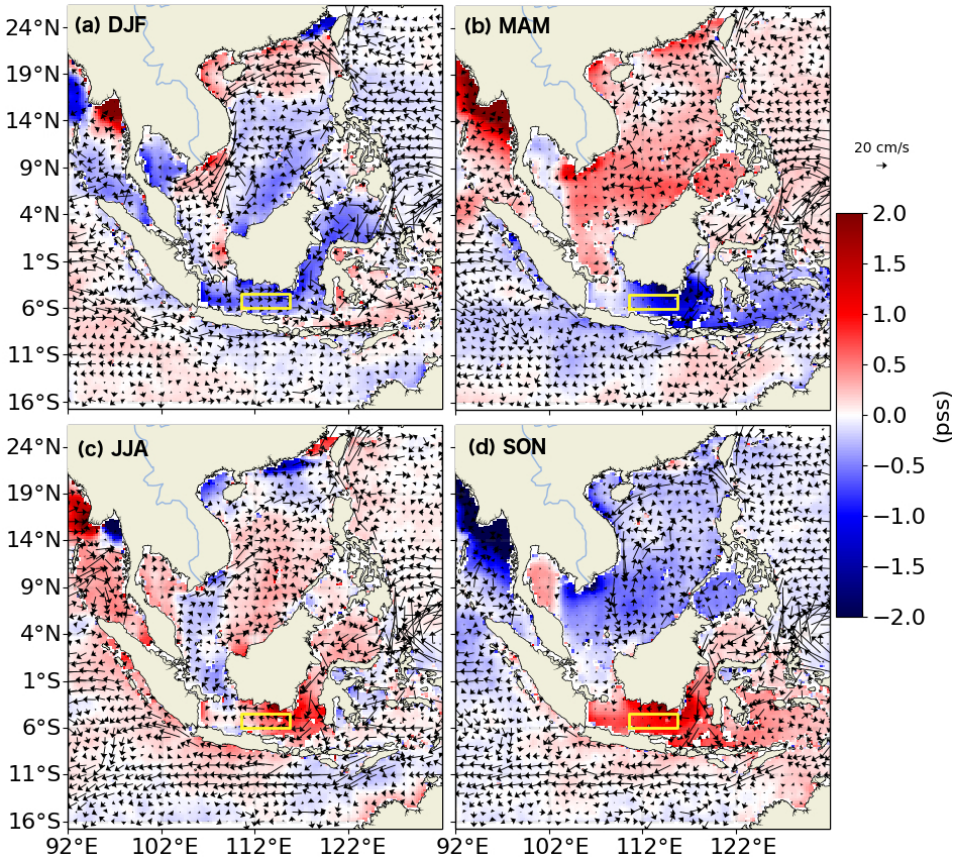


Soil moisture anomalies

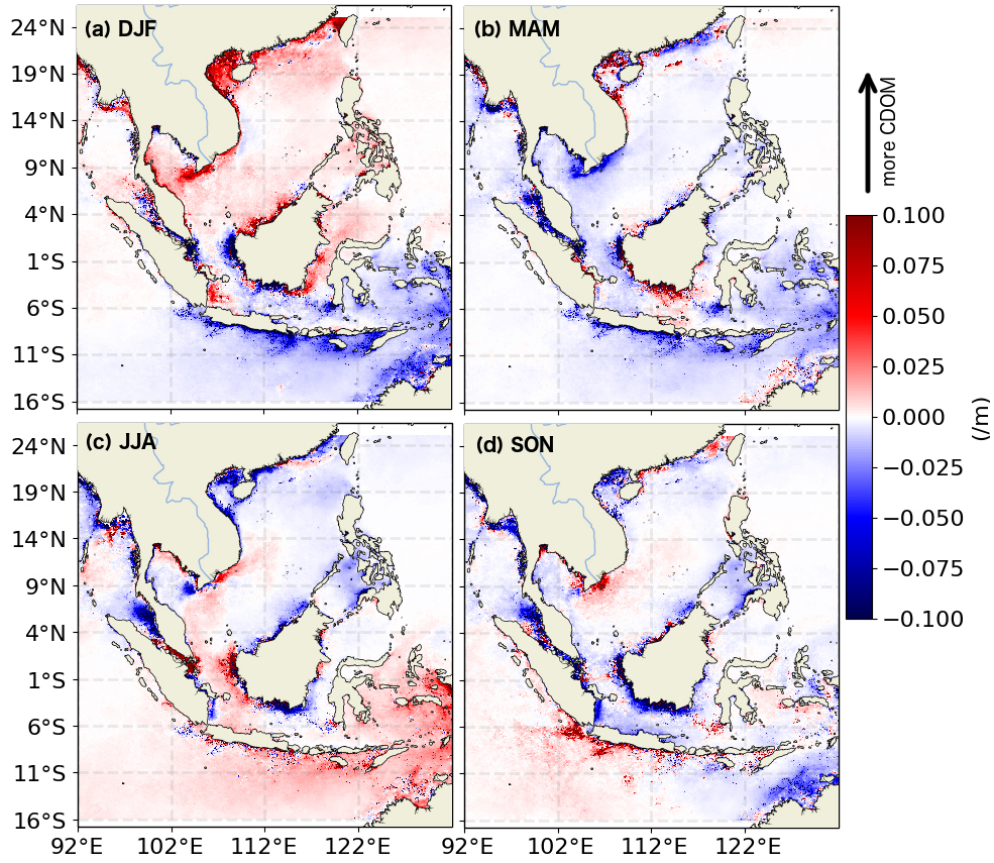


Anti-correlated SSS & ocean color anomalies off Kalimantan suggest the impact of runoff that re-enforces & prolongs the seasonal freshwater plug

SSS anomalies & surface currents

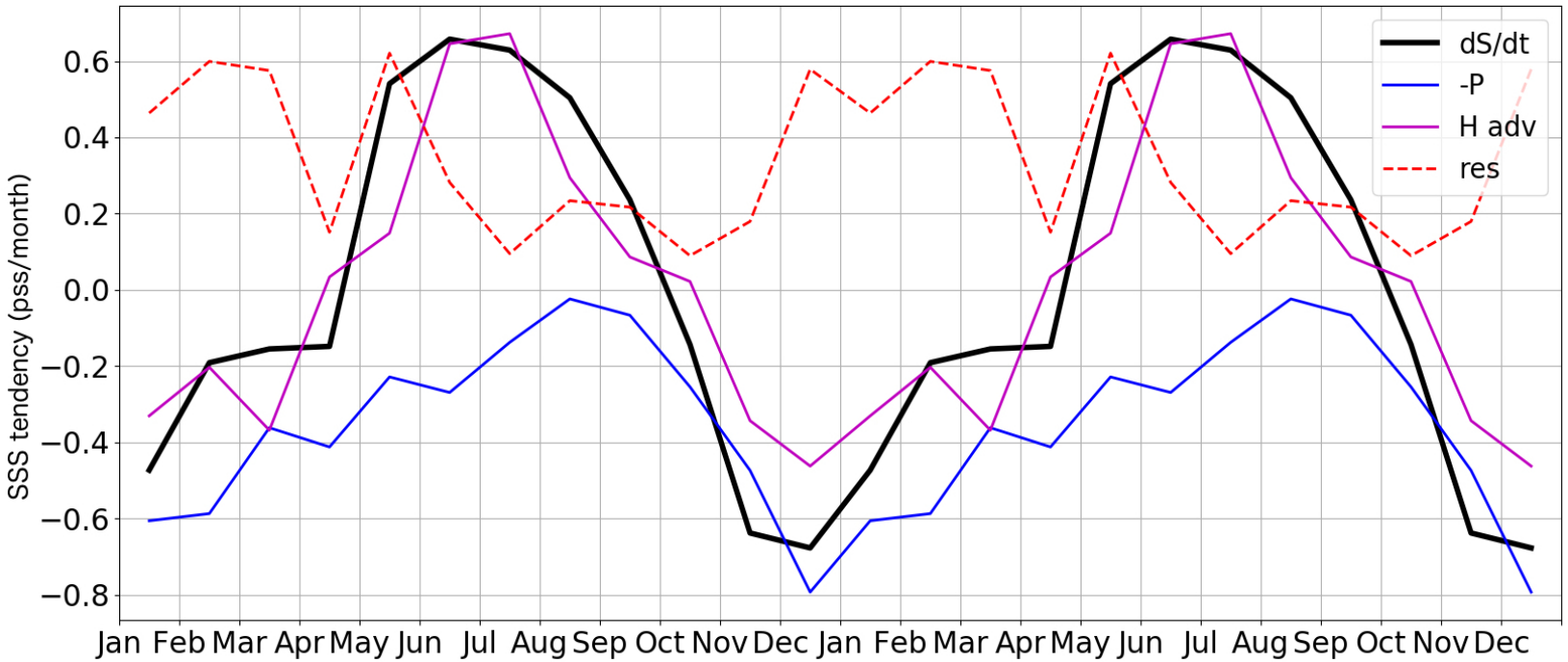


Ocean color (CDOM) anomalies



Seasonal budget of SSS for the Java Sea box

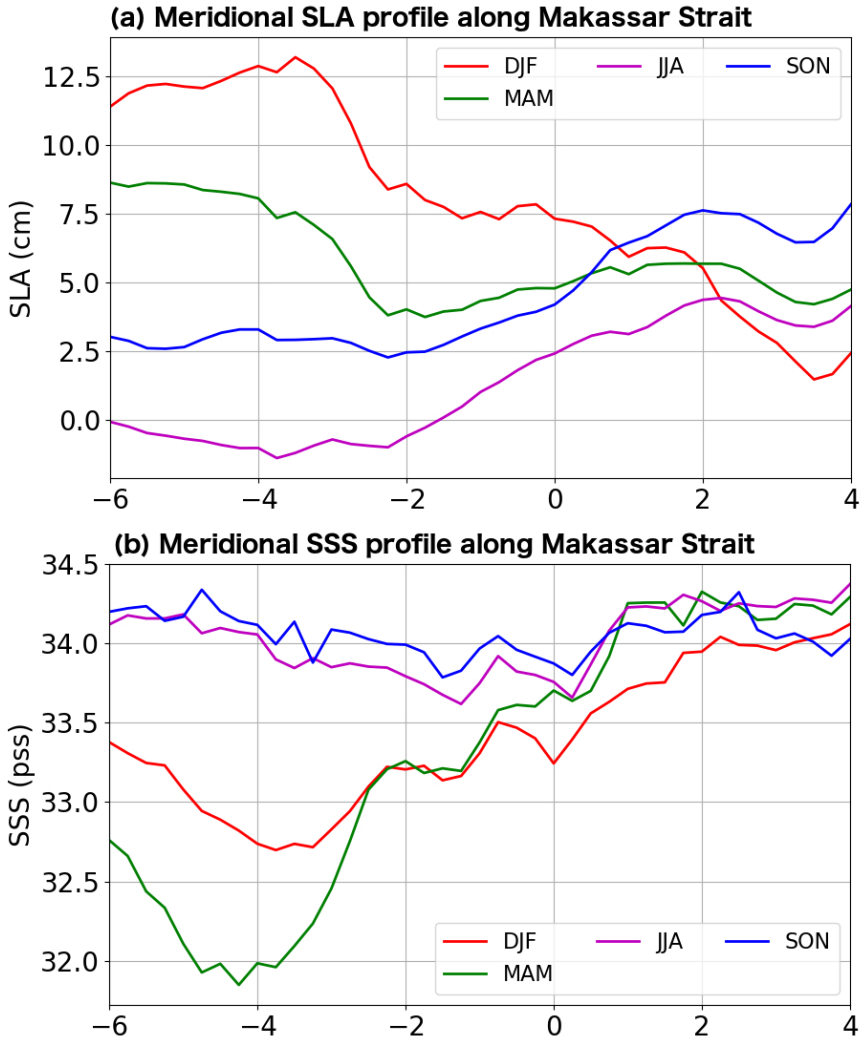
$$\frac{H}{Vol}\iint \frac{dS}{dt}dxdy = \frac{S_0}{Vol}\iint(-P)\,dxdy + Hadv + RES$$



- During boreal winter, precipitation is sufficient to cause the observed freshening
- Horizontal advection re-enforces boreal-winter freshening, and prolongs it to boreal spring
  - Primarily due to advection of freshwater runoff from Kalimantan into the Java Sea (not shown)
- Counteracting effect of the residual term indicates dissipative effects (vertical mixing & evaporation)

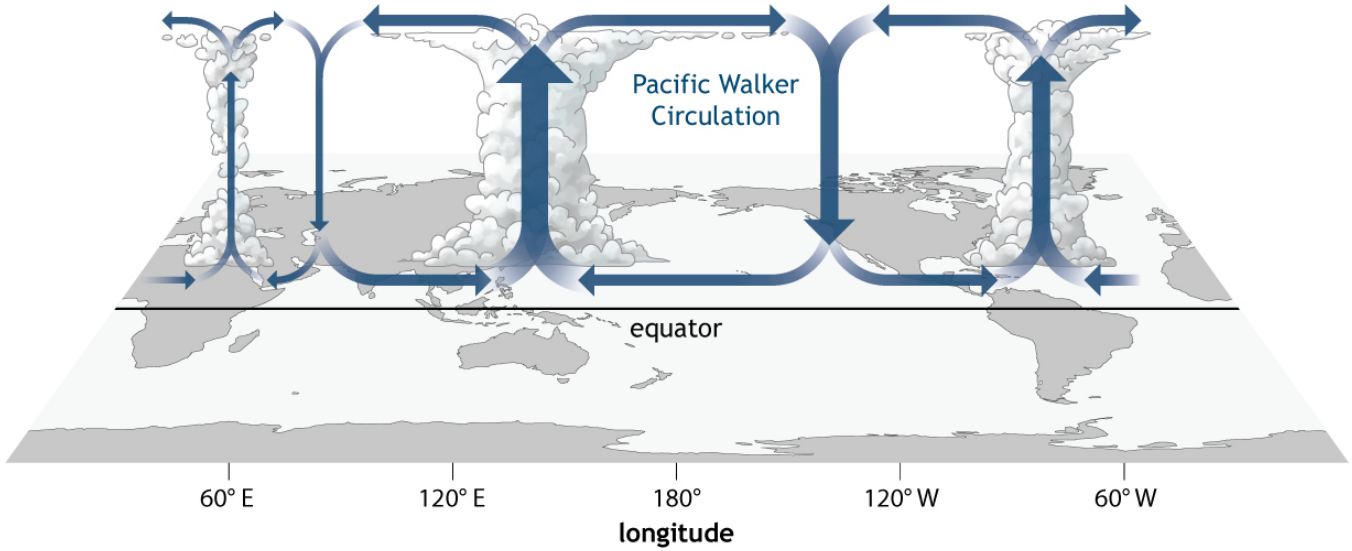
Impact of freshwater plug on meridional pressure gradient along the Makassar Strait: along-strait meridional profiles of SLA & SSS

- Southward increase of SLA correspond to decrease of SSS
- Exemplifies the effect of seasonal freshening on N-to-S pressure gradient that drives the ITF



Summary

- SMAP satellite provided an unprecedented capability to monitor synoptic SSS in the MC region.
- Seasonal freshwater plug in the MC not only exists in boreal winter, but boreal spring as well.
- The major sources of the freshwater plug are MC monsoonal precipitation over the Java Sea & runoff from Kalimantan – different from the previously suggested dominant role of the SCS freshwaters.
- MC water cycle regulates low-latitude chokepoint of global ocean circulation, by affecting seasonality and influencing annual mean



- Implications to longer time scales associated with Indo-Pacific climate variability and changes.
- Sustained satellite SSS such as those from SMAP and SMOS are essential for such studies.